AGING TEMPERATURE EFFECT on HARDNESS and MICROSTRUCTURE of A357 ALUMINIUM ALLOY PART WHICH PRODUCED by GDC and LPDC

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ABSTRACT

A357 aluminium alloy commonly used in automotive, energy, aerospace and engineering applications. In this study, A357 aluminium alloy parts produced by Gravity Die Casting (GDC) and Low Pressure Die Casting (LPDC) methods were used. T6 heat treatment was applied. Firstly, samples are solutionized at 540^o C during 7 hours, then quenched at room temperature water. After that, artificially aged at 150°C and 170°C aging temperatures. Their Vickers hardness changes have observed. For two different casting methods, the hardness increases in the first few hours according to the untreated conditions. Also, dendritic microstructure has changed to homogeneous microstructure after heat treatment. At the beginning, the part which produced by Low Pressure Die Casting method shows higher hardness, lower secondary dendritic arm spacing (SDAS) value and lower porosity against gravity die cast part. After T6 heat treatment LPDC part's advantages against GDC method has partially disappeared.

Keywords: T6 Heat Treatment, A357 Aluminium Alloy, Gravity Die Casting, GDC, Low Pressure Die Casting, LPDC

YAŞLANDIRMA SICAKLIĞININ KOKİL VE ALÇAK BASINÇ DÖKÜM İLE ÜRETİLEN A357 ALÜMİNYUM ALAŞIMLI PARÇANIN MİKRO YAPI ve SERTLİĞİNE ETKİSİ

ÖZET

A357 alüminyum alaşımı yaygın olarak otomotiv, enerji, havacılık ve mühendislik uygulamalarında kullanılır. Bu çalışmada, A357 alüminyum alaşımı parçalar kokil döküm ve alçak basınç döküm yöntemleriyle üretilmiştir. T6 ısıl işlemi uygulanmıştır. İlk olarak numuneler 540° C sıcaklıkta 7 saat boyunca çözeltiye alınmış ve sonrasında oda sıcaklığında su verilmiştir. Bu işlemden sonra, yapay yaşlandırma işlemi 150°C ve 170°C sıcaklıklarda yapılmıştır. Vickers sertlik değişimleri gözlenmiştir. İki farklı döküm yöntemi için de sertlik, ısıl işlemsiz koşullara göre ilk birkaç saat içinde artmıştır. Ayrıca dendritik mikro yapı ısıl işlem sonrasında homojen yapıya dönüşmüştür. Başlangıçta alçak basınç döküm yöntemiyle üretilen parça kokil döküm yöntemiyle üretilen parçaya kıyasla daha yüksek sertlik, daha

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düşük ikincil dendritic kol mesafesi ve daha az porozite göstermiştir. T6 ısıl işleminden sonra alçak basınç döküm yöntemiyle üretilen parçanın, kokil döküm yöntemiyle üretilen parçaya göre avantajları kısmen yok olmaktadır.

Anahtar Kelimeler: T6 Isıl İşlemi, A357 Alüminyum Alaşımı, Kokil Döküm, Alçak Basınç Döküm

1. INTRODUCTION

A357 aluminum casting alloy which was used in this study, use in various applications such as constructional, automotive, aerospace, military and engineering area (MIL-A-21180D, 1984; Wang, 2003; Es-Said et al. 2002).

In aluminum casting, aluminum-silicon alloys have exhibit excellent fluidity, castability and corrosion resistance. The addition of magnesium to aluminum-silicon alloys forms the basis for an extremely important and useful family of compositions that combines outstanding casting characteristics with excellent properties after heat treatment. Corrosion resistance is also excellent, and a low level of thermal expansion is retained (Kaufman J.G. and Rooy E.L. 2004). To improve properties and enhance strength and ductility, aluminum castings often are thermally processed by a series of heating and cooling cycles called heat treatment. This thermal processing involves three basic operations: solution, quench and aging. T6 temper means solution treat and age artificially. In castings, T6 commonly describes optimum strength and ductility (The AFS, 2006). Some aluminum alloys are solution treated at temperatures generally in the range of 400 to 540°C (Canale et al, 2009).

In systems containing aluminum, silicon and magnesium, the strength increases with Mg_2Si, residual stresses decrease, and a homogeneous distribution in porosity is achieved. Magnesium silicide (Mg_2Si) is the soluble phase in important alloys such as 356.0, A356.0 and A357.0 alloys. This phase acts to increase the energy required for deformation of the crystal lattice. Spherical zones convert to needle-shaped particles at points corresponding to peak hardening (Kaufmann, 2004).

Solution heat-treating at relatively high temperature is required to activate diffusion mechanisms, first, to dissolve Mg-rich phases formed during solidification and, then, to homogenize the alloying elements, such as Mg and Si, so as to achieve an elevated yield stress subsequent ageing (ASM Handbook, 1991).

Quenching is usually carried out to room temperature to obtain a supersaturated solid solution of solute atoms and vacancies, in order to achieve an elevated strengthening subsequent ageing (ASM Handbook, 1991). Further, the solution heat treatment changes the morphology of eutectic Si from polyhedral, or fibrous morphology in the modified alloys, to globular structure (Manente, 2011).

In Özkan's M.Sc. thesis, low pressure die casting and gravity die casting methods have compared with regard to secondary dendrite arm spacing (SDAS) and Vickers hardness values (Özkan, 2018). Similarly, tensile properties and fracture behavior of A356 (AlSi7Mg0.3) and A357 (AlSi7Mg0.6) cast aluminum alloys have been investigated in a variety of scientific studies that are dependent on secondary dendrite arm spacing (SDAS) and Mg content (Wang, 2003).

In this study, A357 aluminum alloy parts were produced by gravity die casting and low pressure die casting methods which are popular in industry. After casting, T6 heat treatment applied to specimens which were taken from cast parts. Subsequently, for two different aging temperatures, a hardness change graph was generated for temperatures of 170^{o}C and 150^{o}C respectively for 12 and 24 hours durations. Microstructure changes before and after T6 heat treatment was investigated.

2. EXPERIMENTAL DETAILS

Table.1 Chemical composition of A357 aluminum casting alloy (percentage by mass)

Si	Fe	Cu	Mg	Mn	Zn	Ti
6.5-7.5	0.19 max	0.05 max	0.45-0.70	0.1 max	0.07 max	0.25 max

Table.1 shows the chemical composition of A357 aluminum alloy which was used in this study. Cast parts were produced by gravity die casting and low pressure die casting methods, at “ADT Alüminyum Döküm Teknolojileri” Foundry.

The T6 heat treatment, which is generally used in A356-A357 alloys, was carried out in this study. The samples (20x20x5mm) prepared from the clipbars cast part which are casting by gravity die casting and low pressure die casting methods. T6 heat treatment was carried out in the metallurgical and materials engineering casting laboratory of Dokuz Eylül University by EGEM (Refsan RF 860) brand name and model of furnace.

Solutionizing step of T6 heat treatment was carried out at 540^{o}C temperature during 7 hours. Then samples quenched at room temperature water. Subsequently, they were aged at 150°C and 170°C aging temperatures, up to 24 and 12 hours respectively. During aging process, aging time was increased by hourly. After each hour, vickers hardness of samples were determined.

The hardness tests were also carried out under the load of 1 kg for 10 seconds with the Shimadzu HSV-30 brand and model vickers hardness device. At least 5 tests were carried out for each sample.

3. RESULTS AND DISCUSSION

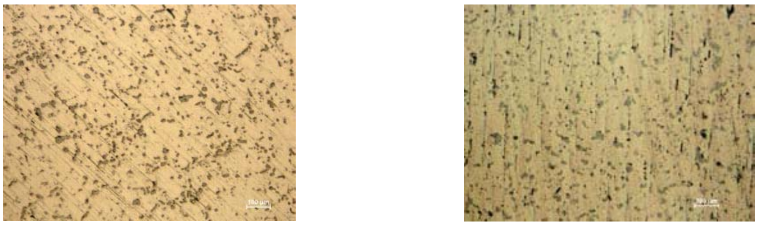
3.1. Microstructural Investigations

Fig.1 shows that dendritic structures of samples which were produced by gravity die casting and low pressure die casting without heat treatment (as cast).

(a) (b)

Fig.1 Dendritic microstructures of as cast **(a)** gravity die cast part, **(b)** low pressure die cast part

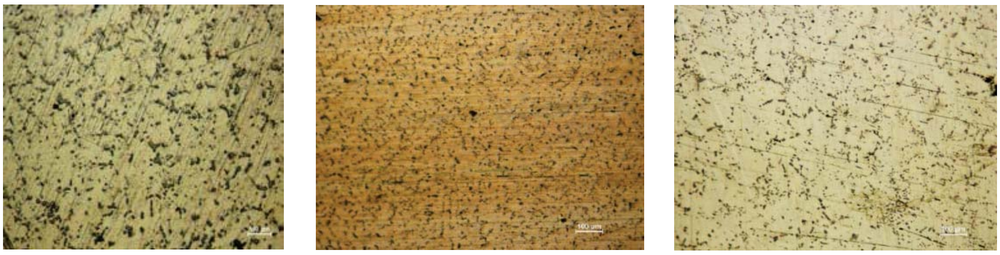
After solutionizing step dendritic microstructure was change to homogenious structure (Fig.4). Silicon-rich phase homogeneously dispersed at aluminum matrix.



(a) (b)

Fig.4 Microstructures of samples after solutionizing (7 hours at 540°C) and quenched at room temperature water (a) gravity die cast (b) low pressure die cast part

In Fig.5 microstructures of samples which were aged at different aging temperature during different aging time, cast by gravity and low pressure die casting methods, has shown.



(a) (b) (c)

Fig.5 Microstructures of samples (a) 12 hours aged at 170°C gravity die cast part (b) 24 hours aged at 150°C low pressure die cast part (c) 3 hours aged at 150 °C gravity die cast part.

3.2. Hardness Test

Table 2 shows the average HV1 hardness values of the cast parts. First row for as cast part (without heat treatment), second row for cooled at furnace after solutionizing, third row shows quenched (at room temperature water) after applying the first heat treatment stage of the T6 heat treatment (7 hours at 540°C).

Table 2. Vickers hardness (HV1) results of samples

	Gravity Die Casting	Low Pressure Die Casting
As Cast	64.6 ±2.21	70.5 ±2.67
After solutionizing (at 540^{o}C, 7 hours) cooled at furnace	41.2 ±1.03	42.1 ±3.98
After solutionizing (at 540^{o}C, 7 hours) quenched at room temperature water	90.3 ±3.35	94.1 ±3.26

For samples aged at 150°C, as shown in Fig.2, the low pressure die cast part shows higher vickers hardness value than the gravity die cast part up to 24 hours.

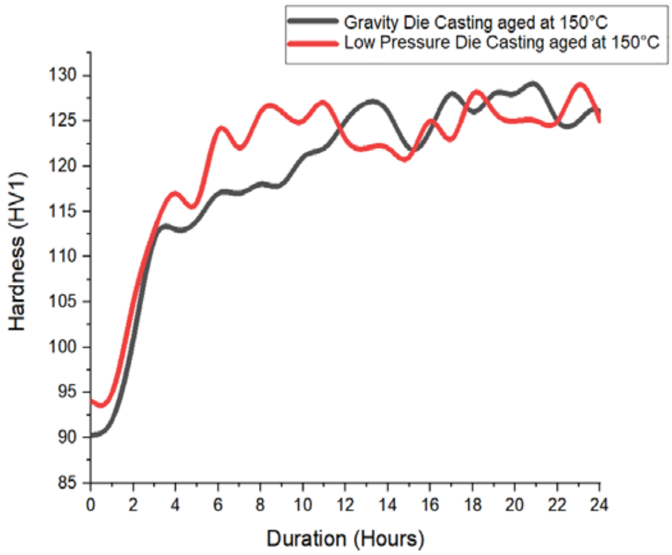


Fig.2 Vickers hardness results of samples which aged at 150°C

The change in hardness of the gravity and low pressure die cast samples aged at 170^{o}C for 12 hours is shown in Fig.3. As can be seen from these figures, two methods show parallel vickers hardness values. They show the highest hardness values in 2-3 hours and then these hardness values decreased.

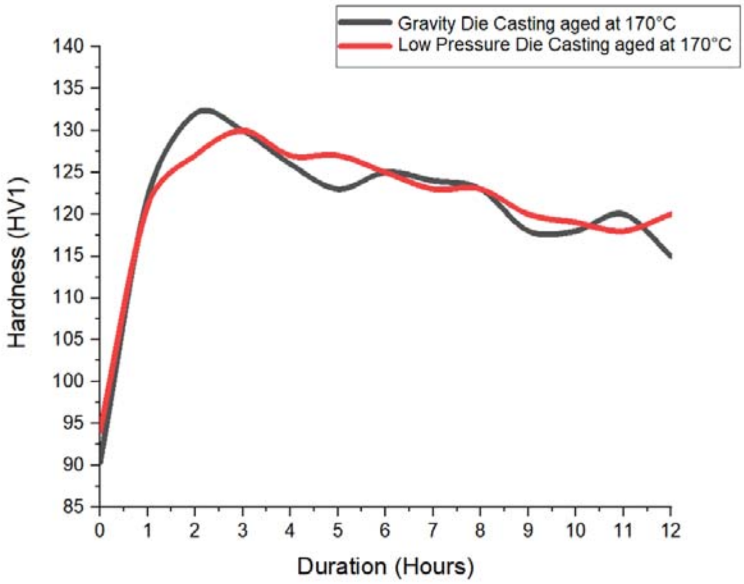


Fig.3 Vickers hardness results of samples aged at 170°C

After T6 heat treatment both samples showed similar hardness results. The Vickers hardness advantage of LDPC parts against GDC parts has considerably disappeared due to the quenching. Nevertheless, LPDC method has advantages against GDC method such as lower porosity, more efficiency, smaller grain size, higher tensile strength, faster cooling etc (Chen, 2016; Bonollo,2005; Özkan,2018).

4. CONCLUSION

To improve the mechanical properties of the A357 aluminum alloy in the aspect of its hardness change due to the performance of the T6 heat treatment is possible with select of suitable solutioning and ageing treatment parameters. Obtaining the highest Vickers hardness, parameters have determined as:

-Solutioning: 540°C during 7 hours,
-Quenching: Room temperature,
-Aging: 170°C during 2 hours.

For this parameters, hardness was observed as 132 HV1.

In T6 heat treatment, structure which became saturated after solutioning and quenching steps, causes an increase in hardness by precipitation of Mg_2Si with aging step. After T6 heat treatment, dendritic structure of gravity and low pressure die cast parts have changed. It effects the hardness and directly mechanical properties of the alloys.

Low pressure cast part shows slightly higher hardness results than gravity die cast part throughout the process. Peak hardness values can be reached in a shorter time as the aging temperature increases. After the T6 process, the result is an increase of the hardness of about 33-40%.

By using the data of this study, it is possible to observe over aging by increasing aging time and continuing to observe hardness changes. Besides, in T6 heat treatment, it is possible to target high energy efficiency processes in the casting sector by evaluating the optimum temperature and time, energy consumption by changing the solutionizing and aging temperature and time.

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